E/CONF.39/A/93
10 Oct.1962
ORIGINAL : ENGLISH

UNITED NATIONS CONFERENCE
ON THE APPLICATION OF SCIENCE AND TECHNOLOGY
FOR THE BENEFIT OF THE LESS DEVELOPED AREAS

Agenda Item: A.4.3.1

Hungary

LOCAL SOURCES OF ENERGY, MICRO-HYDROELECTRIC STATIONS, WITH PARTICULAR EMPHASIS ON THE ELECTRIFICATION OF AGRICULTURE

By Endre GÁDOR,
Technical Development Board,
Budapest, Hungary

Papers have been contributed to the United Nations Conference on the Application of Science and Technology for the Benefit of the Less Developed Areas as working papers for that Conference. They are published as presented by the contributors, and the contents and the views expressed are those of the contributors. (See notes overleaf.)

NOTES

1. Papers selected for inclusion in General Sessions will be available at the Conference in the following official languages of the United Nations: English, French, Russian and Spanish.

2. Papers selected for inclusion in Specialized Sessions will be available at the Conference in only one of the above official languages.

3. Summaries of all papers, as submitted by contributors, will be available at the Conference in the following official languages of the United Nations: English, French, Russian and Spanish.

4. Papers and summaries will not be available for general distribution in advance of the Conference. They will be published in advance in limited quantities only for the use of delegations of participating governments and of other authorized participants. Post-Conference publication and general distribution of the Conference Proceedings will follow United Nations practices as laid down by the United Nations Publications Board.

Local Sources of Energy, Micro-hydroelectric Stations, with particular Emphasis on the Electrification of Agriculture

by Endre GÁDOR,
Technical Development Board
Budapest, Hungary

Determination of demands

/1/ Apart from larger industry centres formed in certain areas, the demand for electric energy of underdeveloped countries is, as a rule, characterized by a low density. Thus, when comparing the different areas, the demands expressed in kW/km^2 or kWh/km^2 values cannot be averaged for the territory of the whole country, as this would result in misleading data; only those areas should be taken into consideration which are inhabited, which are cultivated or suitable for cultivation.

/2/ From the view point of electric energy demand, less developed countries are characterized primarily by a monocultural agriculture. This determines the living standard in the first place, depending on the degree of productivity and on the world market price of the products. Agricultural structure may be on a low level if production methods remain on their original scale and the produce is marketed in its original form. Further, there are possibilities of a low-degree processing as e.g. cleaning, husking, drying, etc. Finally, there may be a certain degree of industrial processing, as milling, storing, etc. of the produce. In the latter case auxiliary plans have to be considered. Demand for electric energy may be increased to a great extent by irrigation and pumping of various kinds necessary for production whereas, for the time being, other types of soil cultivation may be generally disregarded in this respect.

/3/ A higher-degree agricultural cultivation results in the raise of the living standard of the population; thus, agricultural production demands increase parallel to household demands, although these may grow even much faster. Very scarce statistical data are available for the estimation and evaluation of the demands of less developed countries which are at the very beginning of their electrification.

/4/ However, by reverting to an earlier stage of the development of European countries, for which statistical data are available, we may gain some information on the interdependence between agricultural development and electric power demand.

/5/ In certain countries, formerly of a predominantly agricultural character, - for which Central- and East-European countries are good examples - the rural electric energy demand did not excede 1 - 16 kWh/ha of arable land; during the 4o-year period between 192o and 196o this value increased about 2o-fold and now amounts to

20-30 kWh/ha. In the same area, the consumption of the rural population amounted to yearly 10-15 kWh per household; this value equally increased 20-fold, i.e. reached the annual value of 250-300 kWh per household. The low value of 10-15 kWh including the not-electrified households is obtained by dividing the total consumption of the area under consideration by the total number of households. The increment of actual consumption of electrified households is, therefore, much smaller, only 2-3-fold since it amounted, at the date of connexion, to 60-70 kWh/year.

/6/ It goes without saying, that experience gained in European rural electrification cannot, forthwith, be taken as an example. In the first period of the 40-year development, demands increased, to a certain extent, simultaneously with application possibilities, because there were less consumption possibilities available than now. Furthermore, electric machinery /motors, transformers, switchgears, appliances/ represented exceedingly high costs as compared to the market prices of agricultural produce. Practically, besides lighting, there were no household appliances available.

/7/ Electrification started today is realized under quite different circumstances and the easy acquisition of simpler appliances results in a rapid increase of consumption. Whereas in 1920 a rural household required merely lighting which, considering the simplicity of rural life, did not excede 60-70 kWh per year, nowadays the initial consumption attains 150-200 kWh, as household appliances are available in large quantities and at low cost. With the investments for agricultural production the agricultural situation becomes similar. Whereas in 1920 an agricultural unit /farm/ consumed 1-1.5 kWh/ha, nowadays an area of a similar character starts by an annual consumption of 10-15 kWh as soon as the network is able to supply electric power in a sufficient quantity. This is mainly due to the fact that electrically-driven agricultural machinery is available at a considerably lower price as compared to that of the produce than forty years ago.

/8/ However, experience gained in European countries must be cautiously applied to the conditions prevailing in recently liberated territories because the population of these is less aware of the possibilities of utilizing electric power than the population of the European ones. The many millions of rural population are unable to appreciate the economic advantages due to the mechanization of production. But even if they were able to do so, the capital and the professional training necessary for rational use are not available. Therefore when planning the electrification of less developed regions, we must rely on existing intensive economic units /farms/ under proper guidance or on producing and marketing organizations, co-operatives or similar associations recently established. Rural electrification installed can be expected to meet the requirements of lucrativeness, only if such major units are connected to the grid. In case of scattered settlements the installation of minor individual power stations will be indicated for a long time to come. As the networks to be constructed will seldom extend beyond the limits of the settlements, the construction of high or medium-voltage networks may be envisaged only in exceptional cases, i.e. in regions where, owing to favourable natural conditions, the density of the population is greater, where the generation and the distribution of more MW at 15-45 kV medium-voltage will be possible. We do not consider

regions where large energy sources /water or coal/ are available and may facilitate larger industry concentrations. In other regions chiefly household demands, a small-scale agricultural processing and some small-craft consumption may be reckoned with.

/9/ Whatever turn conditions of electrification may assume, some basic considerations must be observed. These are:

/a/ The simplest execution possible of the whole plant, ensuring relatively low investment costs, easy handling, and simple maintenance. The possibility of a simple construction resulting in low efficiency is unimportant if it can be compensated by lower investment costs. With the application possibilities envisaged at an initial stage of electrification /households, small-craft, processing of produce, etc./ the role of a lower efficiency is negligible as compared to the utility and the value of the results attainable.

/b/ Local sources of energy should be utilized to the greatest possible extent.

/10/ Some technical characteristics and economic aspects are given for local power plants corresponding to the above conditions:

Automatically operated micro-hydroelectric stations

/11/ An interesting solution is the GANZ mignon-turbine, a type working well at the initial stage of rural electrification of Hungary, in which the turbine forms a complete unit with the generator and the automatic regulator is, therefore, transportable and ready for installation. Its main advantage is that it does not require permanent handling and supervision. This is necessary only when starting and switching off and during the periodical lubrication of the bearings. The turbine is constructed with a regulator of an exceedingly simple design, with which the number of revolutions can be kept almost constant at any load; this is an important condition for high-quality electric power generation. Thus the water afflux is regulated by the actual power demand. The gross head is of the order of 5-20 m, the water quantities about 220-600 l/sec, and the output 8-80 kW. For the turbines generators are applied with an output of 20-30-45-60-90 kVA. The turbines are of the propeller-turbine type with a vertical shaft and with permanently adjustable fixed and rotating blades. The water inlet is through a cast-iron spiral box. In this box there is a manually driven shutting valve. The water quantity flowing through the turbine is regulated by a bell-shaped lock placed at the base of the leading wheel. Essentially, the turbine regulation is a pendulum provided with a weight working against scroll effect, bringing the bell-shaped lock, in case of revolution variations, into a different balance position, thus adjusting the water absorption capacity of the turbine to the actual output demand. The diagram of the whole design is presented in fig. 1 demonstrating the extraordinary simplicity of the whole construction. The turbine house can be constructed of brick or of timber, but an outdoor execution is equally feasible as shown in fig.2. Beside this, very little under-water construction work is required. The end of the headwater channel is a simple concrete lock wall comprising merely a trash rack and a suitable small sluice, where, beside the small walling around the turbine, the tailwater channel does not need any further installations.

/12/ Another solution of micro-hydroelectric plants is the free radial turbine, the BANKY-turbine, with a simple double-flow, a type ranging between the FRANCIS and the PELTON turbines, but of a much simpler and cheaper make than any of these. In this type the water jet hits the running wheel twice, once tangentially, then leaves it radially, passing through the inner space of the running wheel. The arrangement of the water inlet stub is such that the water jet always reaches the running wheel at an identical angle. The diameter of the running wheel is independent of the amount of water and only its width may vary. In case of larger water amounts two running wheels can be mounted on one shaft. As in the case of all free radial turbines, the running wheel should be placed directly below the tailwater surface and the tailwater level should be kept at a constant height. This turbine is suitable for the utilization of very low heads, viz. in one series at a range between 1.5 and 10 m and in another series at a head between 2 and 60 m. The diagram of the turbine is given in fig. 3, showing that the construction can be adapted to the most simple conditions. Hydraulic structures are of the smallest extent.

/13/ Turbine revolutions are very few therefore coupling with the generator is not always possible and a generator drive with a V-belt might be a more economic solution. Similarly to the above mentioned mignon-turbines, regulations may equally be realized by an automatic and centrifugal system. Both kinds of turbines are constructed expressly for conditions, where independent units can be supplied without network co-operation and it is possible that even with extreme load variations revolution variations will not excede $\pm 5\%$.

Small-size diesel aggregates

/14/ These are suitable where no sufficient amounts of hydropower sources are available. Their output, as referred to motor capacity, varies between 20 and 500 HP, with direct shaft connexion and a three-phase synchronous generator of a corresponding capacity. The number of revolutions of the most popular types is 1000. The erection of these machines in tropical regions is possible even under most adverse conditions, only the problem of the cooling water has to be solved. Under normal conditions cooling is effected in closed circulation; in very hot regions cooling can be effected by forced ventilation, where ventilation capacity may attain even 10-12% of the motor capacity. As regards cooling, it may be mentioned that for 20-25 HP machine units 18-20,000, for 80-100 HP motors 60-70,000 and for 200 HP motors 130-140,000 kcal/h heat reduction should be taken into account.

/15/ Fuel consumption varies between 260-300 g/kWh, according to machine capacity. In forced operation cooling-water supply is about 5%. If the water is too hard a heat exchanger has to be applied, with easy-cleaning pipes, thus motor cooling can be effected by a single filling with distilled water, for the cooling of which fresh water may be used. At small outputs up to 25 HP the starting of the motor can be done manually, above this value, by compressed air. The filling of the air reservoir is effected by a compressor-driven 4-5 HP motor. The capacity of the starting tank ranges between 60 and 100 litres, with a pressure of 35 atm.

/16/ Apart from the substructure, the erection of this machine unit practically does not require any building work, but /where there is no danger of frost/ it may be erected in simple, prefabricated open-side sheds. This is the more expedient as in this case there is no need to provide for a special ventilation of the power house. Up to 500 HP the voltage applied is 400/231 V low-voltage. The switchgear of the machine unit is equally a mass-produced, preferably encased installation provided with the simplest instruments as voltage- and ampere-meters, a period indicator, cooling-degree- and oil-temperature indicators, a generator and generator instruments.

/17/ Thus, for the equipment of the complete power plant the following essential elements are needed:

/a/ aggregate /diesel engine and electric generator/;
/b/ starting gear with auxiliary motor;
/c/ small-size cooling pump /if there is no cooling water available/;
/d/ tank for crude oil, capacity sufficient for about one month;
/e/ tank for crude oil, holding fuel for 1-2 days;
/f/ encased electric switchgear;
/g/ a simple roof construction.

/18/ For operation, the following work is needed:

/a/ daily starting up and lubrication;
/b/ weekly cleaning of filters for crude and lubrication oil;
/c/ Monthly cleaning of air filters, cleaning of boosting nozzle and, as circumstances may require, cleaning of level- and pressure valves of oil pump;
/d/ 3-monthly cleaning of cooling equipment, periodical removal of scaling;
/e/ once a year the motor has to be dismounted and subjected to careful maintenance, however, this is not the task of the local operator, but that of the service.

/19/ From the operations enumerated it is obvious that the technical requirement for the operation of such a plant does not excede that of a truck driver.

Biogas plants

/20/ In agricultural, ie. cultivated areas the use of such power plants is often suggested since sufficient quantities of refuse from plant growing and stock-breeding are available for gasification.

/21/ With a proper processing of such refuse gas of high value can be produced, containing about 65% methane /CH_4/ and 35% carbon dioxide /CO_2/.

/22/ For the production of biogas numerous experiments have been carried out, among which especially the Schmiedt-Eggersglüss and the Passeaux processes have attained widespread application. Large amounts of agricultural waste have been examined in order to determine which to use, with the proper addition of dry substance, for obtaining a good gas mixture. As the most suitable ones chaff, cornstalk, beet-leaf, flax straw, cereal straw, and manure should be mentioned. From these substances about 250-400 litres of gas/kg of dry substance can be gained, with an average methane content of 60%.

The essential elements of this installantion are two or three cylindre-shaped concrete tanks of 8-15 m^3 capacity, filled with prefermented rotting substance, left there for about 2-3 months. The mixing in of agents greatly promotes the fomenting of gases. By the use of several, alternately fed tanks a continuous gas extraction can be ensured. The gas is collected in tanks, from which - especially in tropics and in less developed countries - it can be used, by means of a gas engine, for the generation of electric power and/or, if need be, for the production of industrial steam. The substance remaining after gas extraction becomes nitrogen-enriched and can be used in intensive farming for soil improvement. The caloric value of the gas gained generally ranges between 5300 and 5500 kcal/m^3.

/23/ A very favourable method of gas utilization can be ensured by compressing the gas. As is well-known, gas production is continuous, whereas its use as electric power is subject to great variations. Gas is, therefore, compressed in 1-2 gas containers of 50 l capacity, at 100 atm. Thus 7-14 m^3 biogas can be stored. Assuming the efficiency of the gas engines used at 25%, approximately 1.3 kWh can be gained from 1 m^3 biogas. Although biogas can, according to the above, primarily be utilized as fuel for generating electric energy, in tropical regions it can find an appropriate use for absorption refrigeration. At an ambient temperature of 40° C the consumption of a 200 litre refrigerator amounts to about 2 m^3 per day.

/24/ Investment costs may be assessed as follows:

for building	20 $/$m^3$
for engineering	5 $/$m^3$
electric installations, tubing, design, preparatory work	15 $/$m^3$
totalling	40 $/$m^3$

/25/ In Hungary, there are several biogas plants of this kind in operation. Their spreading has been restrained merely because, by now, the electric power network is available everywhere. However, since gas production yields valuable substances for soil amelioration, it is deemed necessary to increase the number of biogas plants at suitable sites.

/26/ Considering that no uniform standard processes are available and that no experiments have so far been undertaken to investigate the rotting flora of the different tropical regions, especially marshlands for biogas production purposes, the establishment of minor experimental plants in the regions concerned is highly advisable.

Wind power plants

/27/ Since we have no time to dwell on solutions of construction and on results attained, only some economic considerations can be advanced. As a rule, utilized wind power irregularly fluctuates between zero and maximum values and only a certain part of a given wind power strip can be utilized. For small wind power plants a 10-12 m/sec minimum wind velocity can be taken as a base. Beyond these values, dimensions may become necessary whose profitability might be dubious. Similarly, wind velocities below 2-3 m/sec deserve no consideration whatsoever.

/28/ According to experience acquired so far, a satisfactory economical use could be ensured if a 5-10 m/sec wind velocity were available at least for 1500 hours a year, however, it should be borne in mind that the periods of wind velocity and those of power demand do not coincide and, therefore, wind energy can be regarded merely as an auxiliary source. It can be utilized as an independent energy source, only if suitable accumulator storage can be provided for. However, in this case the complexity of installations and the high demands of operational training reduce practicability. In accordance with the above, exceptions can be made only on sites, mostly seashores, where a constant value of wind velocities during longer periods can be reckoned with.

Steam engines

/29/ One of the power engines most suitable for the purpose is the semi-stationary steam engine with a small output of 50-60 HP. These engines are manufactured in series. The average steam pressure in the boiler is 14 atm., the steam temperature in front of the engine is 320-330° C, revolutions are 280/min. The piston steam engine drives the synchronous generator of 40 kW capacity with a fly-wheel belting.

/30/ The boiler construction is suitable for coal and for firing with various kinds of fuel, e.g. hard coal, brown coal, peat, turf, timber waste, straw, rice- and cocoa husk, etc. For the burning of fuels of a low calorific value the boiler is provided with a suitable staggered grate. To ensure proper thermal efficiency, superheaters are installed.

/31/ The compound-system steam engine is provided with low- and high-pressure cylinders, condensers, excenter circular piston drives, a centrifugal regulator, and a manually operated revolution control device.

/32/ If fresh water is unavailable in sufficient quantities, instead of a condenser an exhaust may be applied. The water supply of this installation may be fresh water without any softening. For this purpose the pipes are installed to allow easy dismounting and cleaning.

/33/ Fuel consumption is about 4500 kcal/HPh, steam consumption about 5.8 kg/net hour.

/34/ This plant is suitable for rough operation as it requires simple handling and can be erected outdoors; only a protective roof has to be constructed. For firing agricultural waste, predrying is advisable, which can be done on the sun. The electric installation connected to this engine is identical with that mentioned for diesel plants.

/35/ In each case the possibilities of application of the various types of power plants have to be weighed in accordance with local conditions. Should the provision with energy sources involve difficulties, it becomes evident that primarily the erection of a hydroelectric plant and secondarily the construction of a small steam power plant burning waste fuel have to be taken into consideration. Referred to a 50 kW unit, costs may be assessed as follows:

/a/ Hydroelectric power plant: 8-10,000 $, including a simple mignon-turbine up to 6-10 m head, where no coastal protection work is involved and only a barrage and a sluice have to be built.

/b/ Thermal power plant: 6,000 $, can fire waste fuel too;

/c/ Diesel plant: about 7,000 $;

/d/ Biogas plant, about 10-12,000 $, for the daily production of 250 m^3 steam;

/e/ Wind power station: about 8,000 $.

/36/ These are only the costs of machinery, most probably to be ensured by imports, whereas costs of construction and excavation work, concreting, civil engineering are not included in the above estimates as they may vary considerably according to local conditions and, therefore, may be assessed differently.

/37/ As for operation costs, only the fuel of diesel engines may represent high costs, whereas for the other power plants the energy source is available at the site /water, waste, fuel/ and, as a matter of fact, estimates for these are not possible. When choosing the type of the power plant, apart from the energy source, operation and maintenance possibilities should also be taken into consideration. In this respect, the most suitable solution is the micro-hydroelectric station, the second in rank is the biogas plant, being similarly simple, but possibilities of its installation greatly depend, as mentioned above, on the quality and the availability of waste. In the third place comes the wind power plant, equally requiring a permanent operating staff. As for professional training, the two latter installations require, despite their relative simplicity, a well-trained staff. Here it should be mentioned that, owing to the widespread use of diesel vehicles, properly trained technicians are easily found. As for spare parts, the sequence is about the same. However, it should be pointed out that the steam engine is extremely enduring and its requirement of spare parts extraordinarily low.

/38/ With all the power plants enumerated, generally a very low number of utilization hours has to be taken into account, in many cases not exceeding 1500-2000 hours annually. Therefore, the kWh produced is charged with rather high standing costs. Taking 10,000 $ as the average cost for the erection of a 50 kW power plant and putting maintenance costs, including capital investment, at 10-15%, one kWh generated is charged with a standing cost of 2-2.5 cents; in case of a diesel engine or a steam engine, fuel costs have to be added in accordance with prevailing local conditions.

/39/ When selecting the type of power plant one has to bear in mind that with the increase of demand the capacity assumed will not be sufficient. In the future, power will be supplied from large-size distant power stations and the small power plants will become unnecessary. In these cases they have to be shifted over to sites where they might again become profitable. This applies to any small power plant, except to hydroelectric stations which, as matter of fact, are fixed to a site but, later on, they can be economically connected to the established network. Therefore, although 50-100 kW plants have been considered here, too, the water power available has to be utilized to its maximum capacity and, if not the whole

machinery, so at least the hydrological building constructions should be designed accordingly. However, a later extension of the latter generally encounters various difficulties.

Electric distribution equipment

/40/ The capacity of local power plants is designed for 20-100 kW, although in the case of hydroelectric plants and diesel plants this may be raised up to 200-500 kW. Plants above this capacity are beyond the scope of the present study and they are erected according to quite different considerations.

/41/ The yearly electric energy consumption per capita of developing countries may be assessed at 20-150 kWh. Assuming 1500-2000 utilization hours, a 50 kW capacity power plant is able to supply 70-90,000 kWh energy per year, which may be sufficient for the supply of a population of 800-1500. In this the household demand and the consumption for agricultural production are included which, generally, do not coincide in time.

/42/ As already mentioned, for these outputs and for the dimensions of the regions to be supplied, a low-voltage distribution will be sufficient, which, originating from the power house, may extend to 2-3 km. The line can be constructed in a simple manner with plain wooden poles which, to prevent them from rotting in the soil, should be placed on concrete socles which can be manufactured with the concreting necessary at the time of erection of the power plant. These installations should be manufactured with three-phase and zero conductors, with an earthed neutral and fuses placed at branching points.

/43/ Here the question arises what the optimum voltage should be. It should be uniform, considering that the standard voltage of 400/231 V might seem too high as part of the population is unaware of the contact danger. Some authors propose the application of the lowest 3 x 231 V system. However, this is by no means motivated as the risk is hardly any smaller than in the case of the 400 V voltage. Anyway, great care has to be taken for an effective contact protection. Although they are evidently costlier it is recommendable to apply metal or synthetic encased fittings, resisting mechanical stress as well. In this respect, so far, there is no uniform standpoint, however, requirements of shock-proof fittings should be borne in mind to the highest degree.

/44/ Should the electric power plant, owing to a favourable presence of energy sources, be constructed at a larger capacity than the 50-100 HP mentioned, e.g. in case of a diesel or hydroelectric plant up to 500 kW, it is recommended to transform up the generator voltage and to introduce a uniform voltage here too. 11 kV or 16 kV can be recommended since this voltage still allows to provide greater distances by a single-phase insulating material for poles and with cast-insulated transformers which are mass-produced. Later on higher voltage networks of this kind may easily be connected to high-voltage systems of more distant power stations or networks.

Conclusions

/45/ The characteristics of the electrification of rural areas in less developed countries are:

/a/ Low-capacity, mostly 30-100 kW, individual small power plants should be erected.

/b/ Power plants should, possibly, be fed from local sources of energy, in order to avoid long-distance fuel transport.

/c/ Imported machinery should be cheap, therefore mass-produced machines should be procured.

/d/ It should be borne in mind that the energetic efficiency is a second-rate problem as compared to the simplicity of machine equipment and to the easy operation and maintenance resulting from these. It would be advisable to determine the uniform machine types which could be standardized for this purpose.

/e/ Electricity supply aggregates should, as a rule, be of the outdoor type, only a protecting roof should be provided for. It would be expedient to design simple, light-roof constructions of aluminium or iron tubes, with a cladding made of corrugated iron or slate sheets.

/f/ Electric installations of the power plant should be uniformly constructed for a three-phase 400/231 V voltage, with neutral earthings. The electric equipment of the power house should be of a completely closed, metal-clad type.

/g/ Distribution should be effected, in general, at low-voltage. High-voltage should be used only in case of an output exceeding 200-250 kW, for which the uniform 11-16 kV voltage should be chosen.

/h/ Low-voltage networks should be erected with tarred poles, exceptionally they may be made of plain wood, but anyway, erected on concrete socles. The use of concrete poles should equally be taken into consideration, weighing durability requirements and economic considerations, especially in countries poor in timber.

/i/ As for indoor equipment, special care should be taken for contact protection. Therefore, the uniform use of metal-clad insulated cables and encased fittings is advisable. In accordance with the requirements of initial agricultural electrification internationally applicable provisional standards should be elaborated.

Bibliography

Mocmore: THE BÁNKY WATER TURBINE. Engineering Experiment Station, Oregon College. Bulletin No. 25. 1965

Tsherkasov: ISLEDOVANIE TURBINII BÁNKY, Tashkent, 1939

Bálint and Naszályi: BIOGAS PLANTS, Budapest, 1962 /in Hungarian/

World Power Conference, Belgrade, 1957

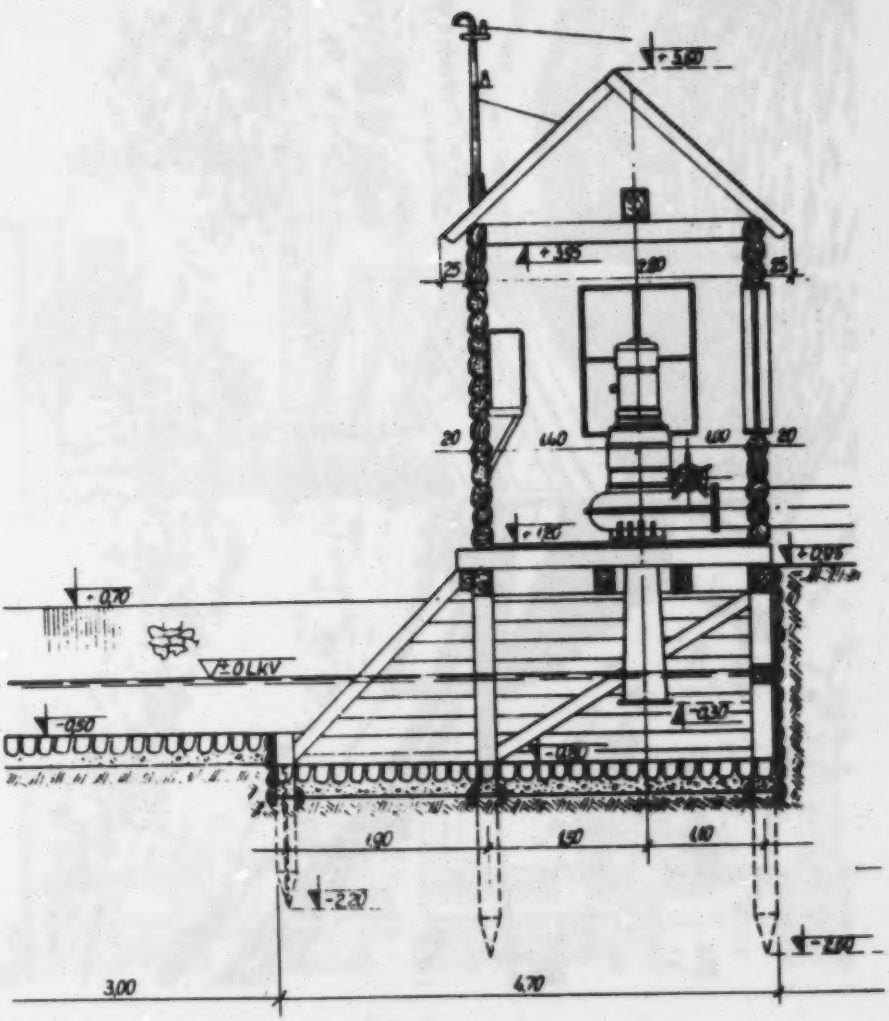
+3.00
+3.35
25
280
25
20
440
440
20
+1.20
+0.95
+0.70
±0.0 LKV
-0.30
-0.30
-2.30
190
150
140
-2.20
-2.90
3.00
4.70

Fig. 1

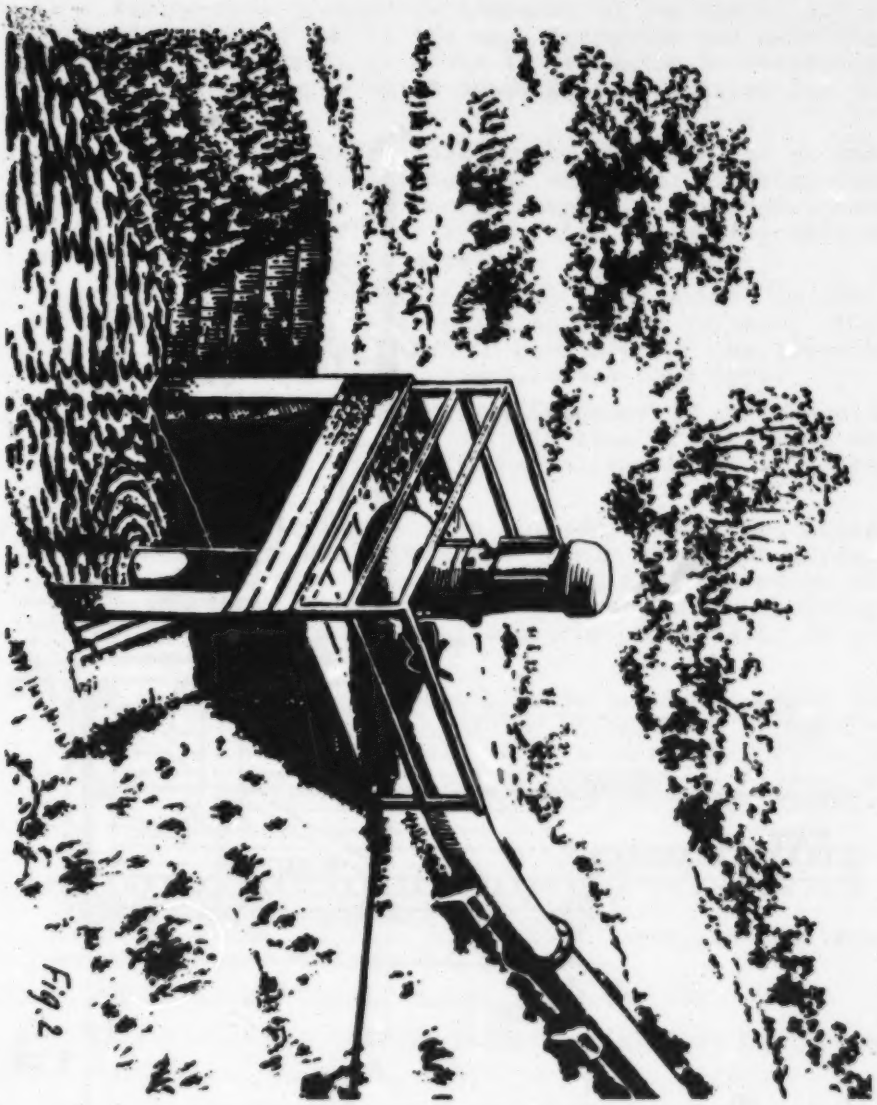

Fig. 2

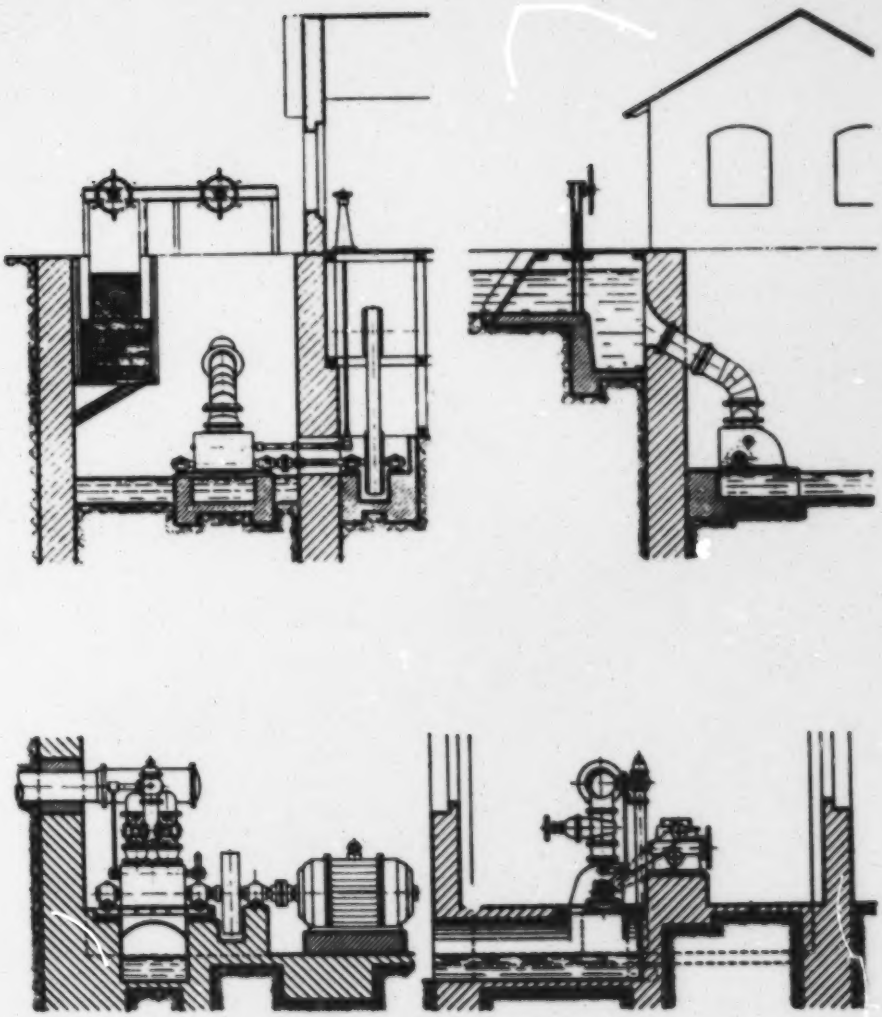

Fig. 3

780 E - Oct.1962 - 1,600